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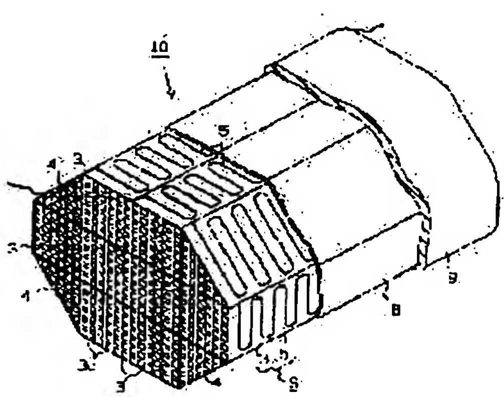
(54) EXHAUST EMISSION CONTROL DEVICE AND STRUCTURAL BODY THEREOF



(57)Abstract:

PURPOSE: To enable regenerative efficiency and durability to be improved and also to facilitate the temperature control in regeneration by raising temperature without temperature nonuniformity in a short period.

CONSTITUTION: One exhaust emission control device 10 is constituted by combining and arranging twelve pieces of filters 3, 4 formed into a honeycomb shape by a porous silicon carbide sintered body. Heaters 5 as a heating element are provided on the outer peripheral part of the filters 3, 4. A seal member 8 serving as a heat resistant filling material is interposed between the filters 3, 4 adjacent to each other, and its periphery is covered by a heat insulating member 9.

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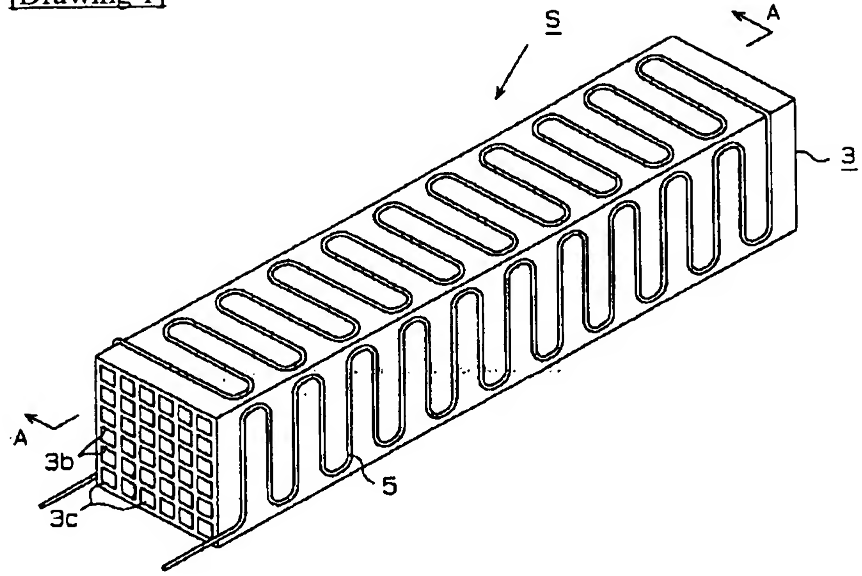
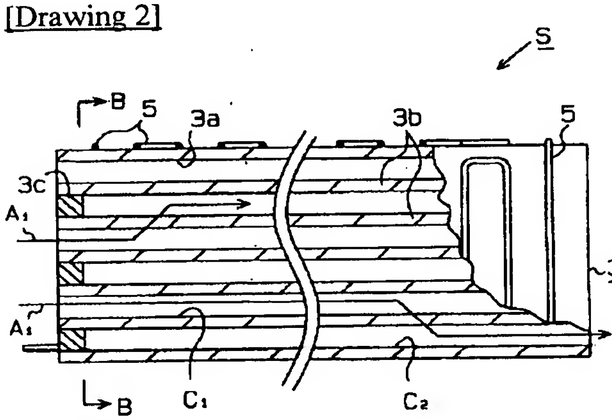
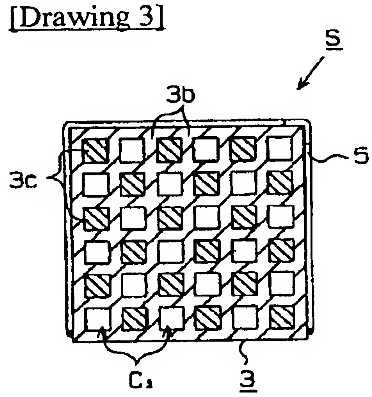
[Drawing 1]



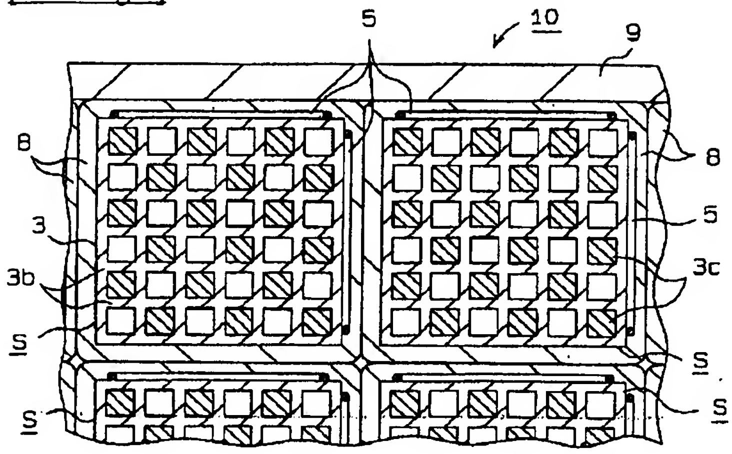
[Drawing 2]



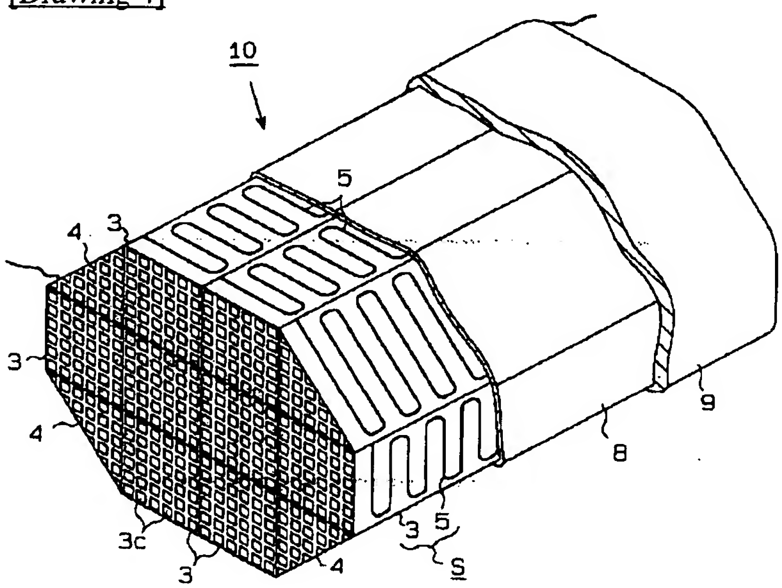
[Drawing 3]



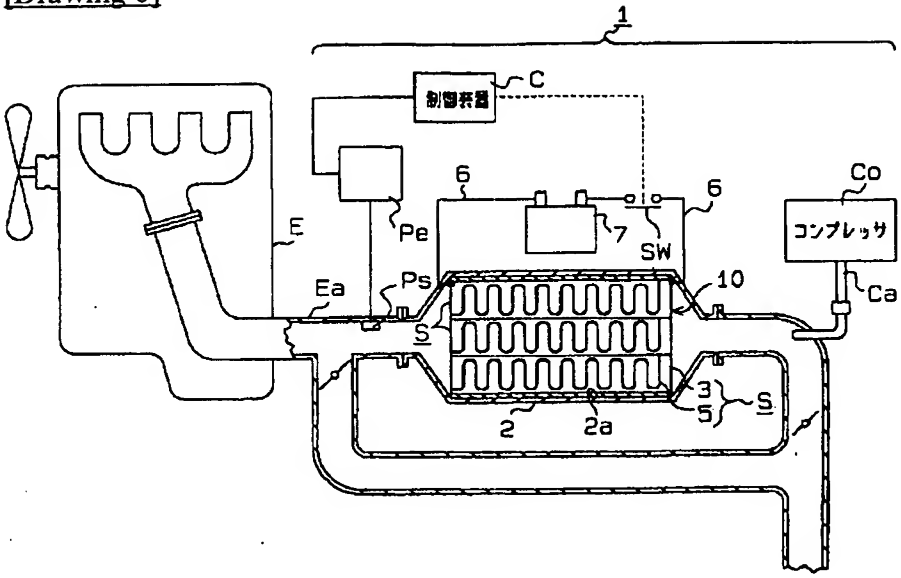
[Drawing 5]



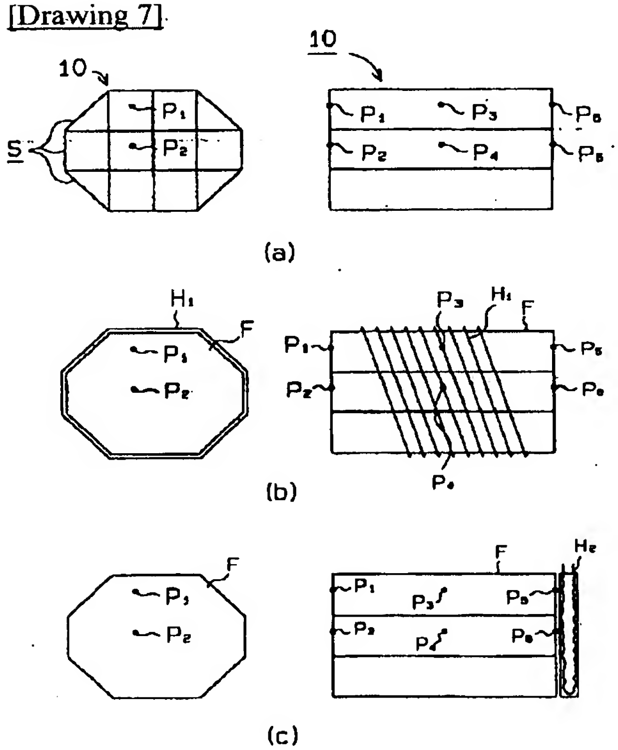
[Drawing 4]



[Drawing 6]



[Drawing 7]



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Japanese Patent Laid-Open No. 7- 54643

(43) Date of publication: February 28, 1995

(54) [Title of the Invention]

Exhaust gas purifying device and structure thereof

(57) [Abstract]

[Object]

To provide an exhaust gas purifying device and its structure which can allow for temperature evaluation for a short time without uneven temperature distribution thus improving regeneration efficiency and durability and facilitating control of the temperature in regeneration.

[Constitution]

Twelve pieces of filters 3 and 4 formed of a porous silicon carbide sintered body in a honeycomb shape are arranged in combination to construct one exhaust gas purifying device 10. In an outer circumference of the filters 3 and 4 is provided a heater 5 as a heating element. Between adjacent filters 3 and 4, a sealing member 8 is interposed as heat -resisting filler and its circumference is coated with a heat insulator 9.

[Claims]

[Claim 1]

An exhaust gas purifying device, wherein a plurality of filters (3 and 4) made of a ceramic sintered body having a porous structure are arranged adjacent to each other and a heating element (5) is interposed between said adjacent filters (3 and 4).

[Claim 2]

The exhaust gas purifying device according to claim 1, wherein a heat-resisting filler (8) is interposed between said adjacent filters (3 and 4).

[Claim 3]

The exhaust gas purifying device according to claim 2, wherein said heating element (5) is placed between said filters (3 and 4) and said heat-resisting filler (8).

[Claim 4]

The exhaust gas purifying device according to claim 2 or 3, wherein said heat-resisting filler (8) has a composition of a ceramic fiber, silicon carbide powder, and an inorganic binder.

[Claim 5]

The exhaust gas purifying device according to any one of claims 2 to 4, wherein said heat-resisting filler (8) is that prepared in a paper form by extrusion molding.

[Claim 6]

The exhaust gas purifying device according to any one of claims 2 to 5, wherein an heat insulator 9 made of a thermally expensive ceramic fiber is placed in its outermost circumference.

[Claim 7]

A structure of the exhaust gas purifying device, composed of the filters (3 and 4) made of ceramic sintered body having a porous structure, and the heating element (5) provided in the outer circumference of the filters (3 and 4).

[Claim 8]

The structure of the exhaust gas purifying device, according to claim 7, wherein said filters (3 and 4) are formed of a porous silicon

carbide sintered body in a honeycomb shape.

[Claim 9]

The structure of the exhaust gas purifying device, according to claim 8, wherein said filters (3 and 4) have an average air pore diameter ranging from 1 μm to 50 μm and a porosity ranging from 30% to 70%.

[Detailed Description of the Invention]

[Field of the Invention]

The present invent ion relates to an exhaust gas purifying device and its component for purification of an exhaust gas from an engine, and specifically relates to the exhaust gas purifying device of a type to burn microparticles contained in the exhaust gas by heat of an electric heater, and its structure.

[Prior Art]

Conventionally, as a filter used for the exhaust gas purifying device of so-called electric heater regeneration type, the filter made by using a ceramic material was proposed. As such ceramic material, cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$) and the like have been generally well known. Using such material, a filter having a honeycomb structure, for example, is made.

Usually, on an end face of such filter is disposed an electric heater as the heating element to heat the filter to a predetermined temperature (600 °C to 800 °C) in regeneration. It is designed such that when the electric heater is energized, fine particles collected on the one end of the filter is ignited to burn finally.

However, in case of the filter hav ing the above described configuration, heat radiated from the heater heats the filter from

the one face side only and therefore, the following disadvantages occurs: a temperature difference tends to occur between the face heated and the face not heated. In addition, if regeneration is continued in this state, a problem occurs that abnormal burning of the fine particles causes local rise of the temperature in the filter to finally cause a crack and a melting loss for a short time. Therefore, conventionally, such measure is taken that various conditions (amount of collection, temperature of the heater, duration time of energization, volume of air for burning to be supplied, and operational conditions of an engine) are controlled in regeneration operation.

[Problems to be Solved by the Invention]

However, because factors influencing the condition s of regeneration are many and complex as described above, it is not easy to control these factors rigidly. In addition, because it is the system heated by radiating heat, there is the following inconvenience: the temperature of the filter not always reaches the temperature of the heater. Even if rigid control is realized by using a computer and the like, it is very difficult to extend a life of the filter to 2000 hours or longer.

As measures for removing the disadvantages of the above described type in which the heater is arranged on the end face it is conceivable to wind the electric heater around an outer circumference of the filter. This method is intended to minimize uneven distribution of the temperature in the filter in regeneration as far as possible by heating the whole filter from the outer circumference side.

However, also in the above described type of the filter in which the heater is arranged in the outer circumference, it is expected

to be difficult to eliminate the uneven distribution inside the filter sufficiently when the filter itself is made in a larger size. In addition, in this case, it is expected that it may take a longer time for the temperature of the filter to be raised up to a regeneration temperature.

The present invention was made in view of the above described situation and it is an object of this invention to provide the exhaust gas purifying device and its structure which can allow for temperature elevation for a short time without uneven temperature distribution thus improving regeneration efficiency and durability and facilitating control of the temperature in regeneration.

[Means for Solving the Problems]

To solve the above descri bed problem, the invention according to the claim 1 consists essentially in the exhaust gas purifying device, wherein a plurality of filters made of a ceramic sintered body having a porous structure are arranged adjacent to each other and a heating element is interposed between said adjacent filters.

In this case, it may be possible to interpose the heat resistant filler between adjacent filters and place the heating element between the filter and the heat resistant filler. On the other hand, the heat resistant filler may have a composition of a ceramic fiber, silicon carbide powder and inorganic binder or may be that prepared in a paper form by extrusion molding. In addition, a thermal expansive heat insulator made of the ceramic fiber may be placed in its outermost circumference.

The invention according to the claim 7 consists essentially in a structure of the exhaust gas purifying device composed of the filters made of ceramic sintered body having a porous structure, and the

heating element provided in the outer circumference of the filters. In this case, the filter may be formed in the honeycomb shape consisting of the porous silicon carbide sintered body, the average air pore diameter may be in a range from 1 μm to 50 μm and the porosity may be in a range from 30% to 70%.

[Operation]

In the invention according to the claim 1, each heater heats the filter surrounding the heater and thus, so the exhaust gas purifying device is heated from inside wholly and evenly. Therefore, the temperature of the exhaust gas purifying device rises evenly for a short time.

In the invention according to the claim 7, the heating element has been previously provided in the outer circumference of the filter and thus, is a very convenient structure to construct the above described exhaust gas purifying device. In addition, this configuration results in a state in which the filter contacts with the heating element and hence, excellent heating efficiency and a good temperature following property.

The exhaust gas purifying device and its structure according to the present invention will be described below in detail. In the present invention, preferably the heat-resisting filler is interposed between the adjacent filters. The aim is to fill the gap formed by combining a plurality of filters to prevent reduction in purification efficiency caused by leak of air. In addition the heat-resistive filler serves also as an adhesive for adhesion between filters.

In addition to heat resistance, the above described heat-resistive filler has preferably elasticity, heat conductivity, and insulating property. Excellent elasticity can release reliably a

thermal stress applied to the filter by heating. Excellent conductivity conducts heat of the heating element to each filter rapidly and evenly to make temperature distribution inside the exhaust gas purifying device even. In addition, excellent insulating property can prevent short circuit between the heating bodies adjacently installed.

The heat-resistive filler has desirably a composit ion of ceramic fiber, silicon carbide powder, and inorganic binder. It is because the filler of such composition has heat resistance, elasticity, thermal conductivity, and insulating property necessary for the above described heat-resistive filler. In this case, suitable ceramic fibers include alumina silicate ceramic fiber, alumina fiber, zirconia fiber, silicon carbide fiber, and silica fiber.

The heat-resistive filler formed by extrusion molding in the paper form is desirably used. With such form it is only required to wind it around the outer circumference of the filter thus facilitating the work of disposing the heat-resistive filler.

According to the present invention, it is preferable to arrange the heating element between the filter and the heat-resistive filler. This is because the configuration, in which the heating element is coated with the heat-resistive filler, can prevent short circuit between the adjacent heating bodies. In addition, such arrangement improves thermal conductivity from the heating element to the filter.

In the present invention, the thermal expansive heat insulator made of the ceramic fiber is preferably installed in the outermost circumference thereof. The term, thermal expansive heat insulator, used herein means a heat insulator having a capability to release the thermal stress thanks to its elastic structure.

The aim is to minimize an energy loss in regeneration by preventing heat loss from the outermost circumference of the exhaust gas purifying device. It also aims to prevent displacement of a position of the filter caused by a pressure of exhaust gas and vibration due to drive of an automobile by expanding the ceramic fiber by heat in regeneration. As the heat insulator, various kinds of ceramic fibers (excluding the silicon carbide fiber) listed above as the heat-resistive filler can be preferably used.

On the other hand, in the present invention, it is desirable that the filter is made in a honeycomb form using the porous silicon carbide sintered body. This is because the porous silicon carbide sintered body is excellent in heat resistance and thermal conductivity. It is also because the honeycomb filter allows a small loss of the pressure when amount of collected fine particles is increased. In addition, it is preferable that the average air pore diameter ranges from 1 μm to 50 μm and the porosity ranges from 30% to 70%. If the average air pore diameter is less than 1 μm, clogging of the filter becomes considerable due to deposition of fine particles. On the other hand, if the average air pore diameter exceeds than 50 μm, fine particles cannot be collected to lower collection efficiency.

If the porosity is less than 30%, the filter may become excessively dense to disturb flow of exhaust gas in an internal part. Thus, collection of fine particles may be become impossible. On the other hand, if the porosity exceeds than 70%, the filter may have excessive gaps to weaken strength and lower collection efficiency of fine particles.

[Embodiments]

Specific embodi ments of an exhaust gas purifying system for a

diesel engine according to the present invention will be described below in detail with reference to Figure 1 to Figure 7.

As shown in Figure 6, the exhaust gas purifying system 1 has a casing made of metal 2. A passage 2a of the casing 2 is communicated to an exhaust gas line Ea of the diesel engine E as an engine. In the casing 2, in order to remove fine particles contained in gas, which is exhausted from the diesel engine E, the exhaust gas purifying device 10 is installed.

As shown in Figure 4, the exhaust gas purifying device 10 according to the present embodiment comprises 8 prism filters 3 and 4 isosceles triangle filters 4 with an rectangular section.

As shown in Figures 1 to 3, prism (33 mm×33 mm×150 mm) filter 3 has a communication hole 3a with almost square section along its axial direction regularly. Each communication hole 3a is separated from each other by an inner wall 3b with a thickness of 0.3 mm. Any one end of a flow-in side or a flow-out side of exhaust gas in each communication hole 3a is sealed in a checkerboard pattern by a sealing piece 3c made of the porous sintered body. As a result, cells C1 and C2 are formed to open in any one of the flow-in side or the flow-out side of the filter 3. On the inner wall 3b of the cell C1 and C2, an oxidizing catalyst made of an element belonging to platinum group and other metal element, an oxide thereof, and the like is supported. The filter 4 has a same structure as that of the filter 3, excepting the sectional shape being a right isosceles triangle. For the filters 3 and 4 according to the present embodiment, the average air pore diameter is set to 14 μm, porosity to 40%, thickness of the wall of to cells to 0.3 mm, and pitch of cells to 1.8 mm.

As shown in Figure 1 to 5, the outer circumference of the filters

3 and 4 is connected to the heater 5 as the heating element. In the present embodiment, the above described heater 5 is a undulated tantalum wire with a diameter of 2 mm. On the other hand, in the present embodiment, the heaters 5 of respective filters 3 and 4 are connected in serial. As shown in Figure 6, a terminal end of the heater 5 is electrically connected to a battery (12 V) 7 through a wire 6. In this case, instead of the 12 V battery 7, a 24 V batter may be used. A power supply higher voltage (100 V power supply for home use or a 200 V commercial power supply) than that of the above described battery 7 may be used.

As shown in Figure 4 and 5, respective filters 3 and 4 are coated by a paper-formed sealing member (thickness 2.5 mm) as the heat resistant filler. Hence, in this exhaust gas purifying device 10 the heating element 5 has been interposed between adjacent filters 3 and 4. On the other hand, in the outermost circumference of the exhaust gas purifying device 10, the heat insulator 9 with the thickness of 15 mm is installed.

Next, an example of a procedure of manufacturing the exhaust gas purifying device 10 will be introduced. Powder prepared by blending a 70% by weight of α-type silicon carbide powder and 30% by weight of β-type silicon carbide powder are wet mixed followed by adding a predetermined amounts of an organic binder (methyl cellulose) and water to the mixture to knead it. Subsequently, this mixture is molded by extrusion to yield a honeycomb molding. Following this step, the molding is dried with a microwave drier. The communication hole 3a of the molding is sealed by a paste for forming a sealing piece 3c made of the porous sintered body followed by drying the paste for forming a sealing piece 3c again dried with the drier. And, the dried

body is defeated at 600 °C and then, it is further sintered at 2200 °C in an argon atmosphere. As the result, the porous honeycomb filter 3 and 4 are obtained.

Then, a 75 parts by weight of the ceramic fiber (alumina silicate ceramic fiber), 10 parts by weight of silicon carbide powder, and 15 parts by weight of silicon dioxide as the inorganic binder are blended and kneaded to mold in a sheet of 3 mm by extrusion. And, the structure S made by adhering the heater 5 to the outer circumference of each filter 3, and 4 is coated with the above described sheet-like sealing member 8. Next, the structure S coated with the sealing member 8 is assembled. Finally, the outermost circumference of the structure S is coated with the heat insulator of ceramic fiber (63% by weight of ceramic fiber, 7% by weight of α Sepiolite, 20% by weight of vermiculite not expanded, and 10% by weight of an organic binder) 9. Then, the desired exhaust gas purifying device 10 as shown in Figure 4 is obtained.

Now flow of exhaust gas will be described when the above described exhaust gas purifying device 10 is placed in a predetermined position and the diesel engine E is started. As shown in Figure 2 by an arrow A1, exhaust gas is first led to inside of the cell C1 open to the flow-in side of the filters 3 and 4. Then, exhaust gas passes through the inner wall 3b and is led to inside of the adjacent cell C2, namely, C2 open to the flow-out side. In this occasion, movement of fine particles contained in exhaust gas is inhibited by the inner wall 3b. Thus, only fine particles are trapped by the inner wall 3b. And, exhaust gas purified passes through the inside of the cell C2 open to the flow-out side and is finally discharged from the filters 3 and 4.

In the exhaust gas purifying system 1 according to the present example, as shown in Figure 6, in a position upstream of the exhaust gas purifying device 10 in the exhaust gas line Ea, a pressure sensor Ps is installed. This pressure sensor Ps is electrically connected to a piezoelectric-crystal element Pe. And, the piezoelectric-crystal element Pe is adapted to, according to a detection signal outputted from the pressure sensor Ps, output a predetermined electric signal to a controlling apparatus C. The controlling apparatus C is adapted to, according to the detection signal from the piezoelectric-crystal element Pe, turn on and turn off a switch Sw provided on the wire 6.

On the other hand, in the position downstream of the exhaust gas purifying device 10 in the exhaust gas line Ea, an air supply pipe Ca is installed. The air supply pipe Ca is connected to a compressor Co. Hence, in regeneration, through the air supply pipe Ca, a secondary air is supplied to inside of the exhaust gas line Ea for acceleration of burning.

Now, characteristics evaluation tests conducted with the exhaust gas purifying devices 3, 4 incorporated into the above described exhaust gas purifying system 1 will be described. In these characteristics evaluation tests , 2 kinds of the exhaust gas purifying device made of cordierite were preferred as comparative examples 1 and 2 to the practical examples. In the comparative example 1, as shown in Figure 7 (b), the heater H1 was wound around the outer circumference of the filter F. In the comparative example 2 as shown in Figure 7 (c), the heater H2 was installed on the downstream side end face of the filter F.

And, the diesel engine E was started to first collect fine

particles contained in exhaust gas with the exhaust gas purifying device 10. In this occasion, the control apparatus C monitored change in the pressure inside the exhaust gas line Ea in collection operation. And, until the above described pressure value reaches a certain value, the collection operation was continued. The amount of fine particles collected during this operation was calculated to be 15 g/liter. This value calculated was calculated on the basis that the volume of the exhaust gas purifying device 10 was assumed as a total amount of the parts of gas passed through to measure change in weight before and after the collection operation.

After detecting completion of the collection operation, the switch Sw was close by the controlling apparatus C to start applying electricity to the heater 5. After a predetermined time passed since electrification started (after the stage to raise the temperature was completed.) the compressor Co was operated to supply the secondary air for acceleration of burning from the air supply pipe Ca in a rate of 20 cm ^{3}/minutes.

And, as shown in Figure 7 (a) the temperatures T1 to T6 in respective positions P1 to P6 of the exhaust gas purifying device 10 were measured in a time sequence with a thermocouples. For the comparative examples 1 and 2, similarly, the temperatures T1 to T6 were measured in respective positions P1 to P6.

In this test, the stage from start of electrification until the average value of the temperature T1 to T6 reached 600 °C was named "temperature rise stage." And, the stage from start of supply of the secondary air after completion of the temperature rise stage to completion of burning of fine particles was named "regeneration stage." And, the time (minutes) passed for the temperature rise stage

and the regeneration stage were calculated which were summed as electrification time (minutes). In addition, for each of the temperature rise stage and the regeneration stage, the maximum temperature difference ΔT (°C) in each position P1 to P6 was calculated. These results are shown in Table 1.

On the other hand, in this test, the time (time) before filters 3 and 4 constituting the exhaust gas purifying device 10 develop to crack was determined. Similarly, the above described test was conducted for the comparative examples 1 and 2. The result is shown in Table 2.

[Table 1]

	Electrifying time (min.)		Maximum temperature difference ΔT (°C)	
	Temperature rise stage	Regeneration stage	Temperature rise stage	Regeneration stage
Example	10	2	40	30
Comparative example 1	35	6	120	350
Comparative example 2	60	15	250	380

[Table 2]

	Time (hour) before crack occurs						
	- 1000	2000	3000	5000	10000	15000	20000
Example	O	O	O	O	O	O	O
Comparative example 1	O	O	×	-	-	-	-
Comparative example 2	O	×	-	-	-	-	-

In the table, O and × represent no crack occurrence and occurrence of crack, respectively.

As apparent from the Table 1, the example showed the shorter times for temperature rise stage and also regeneration stage in comparison with those of the comparative examples 1 and 2. In addition, the maximum temperature difference ΔT (°C) in respective positions P1 to P6 was smaller than that of the comparative examples 1 and 2.

In other words, according to the present example, the tempe rature of the exhaust gas purifying device 10 can be raised without uneven temperature distribution for a short time and can carry out regeneration for a short time. In addition, the shortened time for the temperature rise stage and the regeneration stage shortens a total electrification time. Thus, in accordance with the example, electric energy can be less for efficient regeneration. In addition, there is the following advantage: in the example, the maximum temperature difference ΔT (°C) in respective positions P1 to P6 becomes relatively smaller and thus, temperature control in regeneration step can become easy.

In addition, as apparent from the Table 2, in the example, use for a time over 20000 hours did not cause a crack of filters 3 and 4. On the contrary, the comparative examples 1 and 2 did not allow for the use for 3000 hours and 2000 hours, respectively. In conclusion, it is found that the exhaust gas purifying device 10 according to the present example is very excellent in durability in comparison with the comparative examples 1 and 2.

In addition, according to the configuration of the exhaust gas purifying device 10 of the present example, it is found that even if supply of the secondary air is small, reliable regeneration can be carried out. Consequently, the compressor Co may be smaller.

The present invention is not limited to the above described example, but can be modified to the following configurations. For example,

(a) Number of combination of the structure S may not be 12 as in the above described example, but can be any number. In this case, it is also possible to use the structures having different sizes and

shapes in an appropriate combination. It is particularly advantageous to have a configuration characterized in that a plurality of the structures S are combined in making a large-sized exhaust gas purifying device.

(b) The exhaust gas purifying device 10 according to the above described example can be considered as a large filter divided into a plurality of partitions in the axial direction. Thus, for example, following variations are possible: in which the filter is divided into a donut shape, or it is vertically divided in the axial line direction.

(c) Other than the honeycomb filters 3 and 4 as shown in the above described example, three-dimensional network structure, foam-shape, noodle-shape, or fiber-shape, for example, can be of course employed. In addition, as a ceramics material for filters 3 and 4, those other than silicon carbide can be of course selected.

(d) The heater 5 is not limited to the metal wire as shown in the above described example. The heater 5 can be prepared by such methods as metallization, printing of a conductor paste, or sputtering.

(e) The sealing member 8 as the heat resistant filler may not always that of paper form as shown in the example. For example, a method is possible in which a layer of the heat resistant filler may be formed by direct application of slurry before molding in the paper form to the outer circumference of the filters 3 and 4.

(f) In addition, in case of the method for manufacturing the above described (e) using the slurry for forming the filters 3 and 4 and the slurry for forming the heat resistant filler layer, the above described both the slurries may be simultaneously extruded by one

extrusion molding machine. In this method, the slurry for formation of filters 3 and 4 is extruded from a central part of a jig of the extrusion molding machine and also simultaneously, the slurry for formation of the heat resistant filler layer is extruded from the outer circumference of the above described jig. This method allows efficient preparation of the structure S for a short time.

(g) In constructing the exhaust gas purifying device 10, the structure S comprising filters 3 and 4 having the heater 5 as in the above described example may be not always used. For example, the exhaust gas purifying device 10 can be prepared by a procedure in which after a plurality of filters 3 and 4 are combined, the heater 5 is inserted in a gap between adjacent filters 3 and 4 and then, the slurry for formation of the heat resistant filler layer is filled.

(h) Instead of the example in which respective heater 5 are wired serially, these may be wired in parallel.

[Advantages of the Invention]

As described above in detail, according to the e xhaust gas purifying device and structure thereof of the present invention, the temperature can be evenly elevated for a short time and thus, the following excellent effects are obtained : regeneration efficiency and dura bility can be improved and also temperature control in regeneration operation can be facilitated.

[Brief Description of the D rawings]

[Figure 1]

Figure 1 is a perspective view showing the structure of the exhaust gas purifying device.

[Figure 2]

Figure 2 is an enlarged sectional view partially broken along line A-A of the Figure 1.

[Figure 3]

Figure 3 is an enlarged sectional view taken along line B-B of the Figure 2.

[Figure 4]

Figure 4 is an enlarged sectional view partially broken showing the exhaust gas purifying device comprising a plurality of the structural bodies.

[Figure 5]

Figure 5 is a partially enlarged sectional view showing the exhaust gas purifying device .

[Figure 6]

Figure 6 is a schematic sectional view showing the state where the exhaust gas purifying device is incorporated .

[Figure 7]

Figure 7(A) to (c) are schematic diagrams illustrating a method for carrying out test for the example and the comparative examples 1 and 2.

[Description of Symbols]

3 and 4 ... Filter, 5 ... Heater as a heating element, 8 ... Sealing member as the heat resistant filler, 9 ... Heat insulator, 10 ... Exhaust gas purifying device, S ... Structure.

Figure 6

C Controlling apparatus

Co Compressor